Claims

[c1] 1.A matching layer for an ultrasound probe comprising a plurality of sublayers attached together, the sublayers having different impedance values, a first sublayer of the plurality of sublayers being disposed adjacent to an element of a transducer of the ultrasound probe, a last sublayer of the plurality of sublayers being disposed adjacent to a target, the impedance value of the first sublayer being less than or equal to the impedance value of the element of the transducer, the impedance value of the last sublayer being greater than or equal to the impedance value of the target, the impedance values of the sublayers decreasing from the first to the last sublayer.

[c2] 2.The matching layer for an ultrasound probe of claim 1 wherein the impedance value of the first sublayer is preferably within 20 percent of, more preferably within 10 percent of, and most preferably equal to the impedance value of the transducer element.

[c3] 3.The matching layer for an ultrasound probe of claim 1 wherein the impedance value of the last sublayer is preferably within 20 percent of, more preferably within 10 percent of, and most preferably equal to the impedance value of the target.

[c4] 4.The matching layer for an ultrasound probe of claim1 wherein each of the sublayers has a thickness of less than about 100 μ m, preferably less than about 75 μ m, more preferably less than about 50 μ m, and most preferably less than 10 μ m.

[c5] 5.The matching layer for an ultrasound probe of claim 1 wherein the matching layer has a thickness of about one-quarter wavelength of a central frequency of the transducer element when the transducer element is energized.

[c6] 6.The matching layer for an ultrasound probe of claim 1 wherein the matching layer has a thickness equal to an odd multiple of one-quarter

wavelength of a central frequency of the transducer element when the transducer element is energized.

[c7] 7.The matching layer for an ultrasound probe of claim 6 wherein the odd multiple is smaller than or equal to 21.

[c8] 8.The matching layer for an ultrasound probe of claim 1 wherein a sublayer is made of a composite material having at least two components.

[c9] 9.The matching layer for an ultrasound probe of claim 8 wherein the at least two components have different impedance values and each of the components forms a pattern in the sublayer.

[c10] 10.The matching layer for an ultrasound probe of claim 9 wherein the sublayer is made by a process comprising the steps of:
forming a sheet of the first component, the sheet having a thickness of about one-quarter wavelength or an odd multiple of one-quarter wavelength of the central frequency of the transducer material;
forming openings in the sheet; and
filling the openings with at least one other component.

[c11] 11.The matching layer for an ultrasound probe of claim 10 wherein the first component is selected from the group consisting of nickel, aluminum, tin, lead, zinc, titanium, zirconium, iron, cobalt, copper, manganese, chromium, tungsten, gold, silver, magnesium, silicon, ceramics, metal oxides, metal sulfides, metal nitrides, glass, cement, mixtures thereof, and alloys thereof; and the at least one other component is selected from the group consisting of rubbers, epoxy, polystyrene, polyurethane, polyethylene, polypropylene, polybutylene, polyvinyl chloride, polybiphenyl chloride, polymethylmethacrylate, polycarbonate, copolymers thereof, and mixtures thereof.

[c12] 12.The matching layer for an ultrasound probe of claim 10 wherein the first component is selected from the group consisting of rubbers, epoxy, polystyrene, polyurethane, polyethylene, polypropylene, polybutylene,

polyvinyl chloride, polybiphenyl chloride, polymethylmethacrylate, polycarbonate, copolymers thereof, and mixtures thereof; and the at least one other component is selected from the group consisting of nickel, aluminum, tin, lead, zinc, titanium, zirconium, iron, cobalt, copper, manganese, chromium, tungsten, gold, silver, magnesium, silicon, ceramics, metal oxides, metal sulfides, metal nitrides, glass, cement, mixtures thereof, and alloys thereof.

[c13] 13.The matching layer for an ultrasound probe of claim 8 wherein the at least two components are mixed together.

[c14] 14.The matching layer for an ultrasound probe of claim 13 wherein a binder is mixed with the at least two components.

[c15] 15.A method of making a matching layer for an ultrasound probe comprising the steps of:
forming a plurality of sublayers having different impedance values; and
attaching the sublayers together such that a first sublayer, being disposed adjacent to an element of a transducer of the ultrasound probe, has an impedance value equal to or less than an impedance value of the transducer element; the last sublayer, being disposed adjacent to a target, has an impedance value greater than or equal to the impedance value of the target; and the impedance values of the sublayers decrease from the first to the last sublayer;
wherein the forming of each of the sublayers comprising the steps of:
forming a sheet of a first material;
forming openings in the sheet; and
filling the openings with at least one other material having a different impedance than the impedance of the first material.

[c16] 16.The method of making a matching layer for an ultrasound probe of claim 15 wherein the step of forming the sheet of the first material is done by a method selected from the group consisting of electroplating, electrophoresis, tape casting, slip casting, and gel casting; the step of

forming openings in the sheet is done by a method selected from the group consisting of etching, cutting, photolithography, and laser ablation; and the step of filling the openings is done by a method selected from the group consisting of spraying, inkjet printing, screen printing, tape casting, slip casting, and gel casting.

[c17] 17.A method of making a matching layer for an ultrasound probe comprising the steps of:
forming a first sublayer on a temporary substrate;
forming at least one other sublayer on the first sublayer to provide a plurality of sublayers comprising a first and a last sublayer, the plurality of sublayers being attached together; and
removing the plurality of sublayers from the substrate;
wherein impedance values of the sublayers change monotonically from the first to the last sublayer.

[c18] 18.The method of making a matching layer for an ultrasound probe of claim 17 wherein the step of forming the sublayers is done by a method selected from the group consisting of inkjet printing, screen printing, tape casting, slip casting, gel casting, electrophoresis, and electroplating.

[c19] 19.The method of making a matching layer for an ultrasound probe of claim 18 wherein each sublayer is a composite of at least two materials having different impedance values and the composite has a composition selected such that impedance values of the sublayers as arranged in the matching layer change monotonically from the first to the last sublayer.

[c20] 20.The method of making a matching layer for an ultrasound probe of claim 15 wherein the first material is selected from the group consisting of nickel, aluminum, tin, lead, zinc, titanium, zirconium, iron, cobalt, copper, manganese, chromium, tungsten, gold, silver, magnesium, silicon, ceramics, metal oxides, metal sulfides, metal nitrides, glass, cement, mixtures thereof, and alloys thereof; and the at least one other material is selected from the group consisting of rubbers, epoxy, polyurethane, polyethylene,

polypropylene, polybutylene, polyvinyl chloride, polybiphenyl chloride, polymethylmethacrylate, polycarbonate, copolymers thereof, and mixtures thereof.

[c21] 21.The method of making a matching layer for an ultrasound probe of claim 15 wherein one of the at least two materials is selected from the group consisting of nickel, aluminum, tin, lead, zinc, titanium, zirconium, iron, cobalt, copper, manganese, chromium, tungsten, gold, silver, magnesium, silicon, ceramics, metal oxides, glass, cement, mixtures thereof, and alloys thereof; and another of the at least two materials is selected from the group consisting of rubbers, epoxy, polyurethane, polyethylene, polypropylene, polybutylene, polyvinyl chloride, polybiphenyl chloride, polymethylmethacrylate, polycarbonate, copolymers thereof, and mixtures thereof.

[c22] 22.A method of making a matching layer for an ultrasound probe comprising the steps of:

providing a first material in a particulate form, the first material having a first impedance value;

forming a plurality of sheets of the particulate first material; said plurality of sheets having different porosities;

sintering the particulate first material to produce porous sheets of the first material;

infiltrating the porous sheets of the first material with a liquid of a second material having a second impedance value different from the first impedance value;

solidifying the second material to form a plurality of sublayers having varying sublayer impedance value;

attaching the sublayers together to form the matching layer for an ultrasound probe in an order such that the sublayer impedance value varies monotonically through the matching layer.

[c23] 23.The method of making a matching layer for an ultrasound probe of claim

22 wherein the first material has a higher impedance value than the second material.

[c24] 24. The method of making a matching layer for an ultrasound probe of claim 22 wherein the first material is selected from the group consisting of nickel, aluminum, tin, lead, zinc, titanium, zirconium, iron, cobalt, copper, manganese, chromium, tungsten, gold, silver, magnesium, silicon, ceramics, metal oxides, glass, cement, mixtures thereof, and alloys thereof; and the second material is selected from the group consisting of rubbers, epoxy, polyurethane, polyethylene, polypropylene, polybutylene, polyvinyl chloride, polybiphenyl chloride, polymethylmethacrylate, polycarbonate, copolymers thereof, and mixtures thereof.